CHAPTER 8

GUIDELINES FOR DESIGN OF STORM DRAINS IN THE ARCTIC AND SUBARCTIC

8-1 **GENERAL.** Chapter 4 provides general design criteria for drainage and erosion control structures commonly used for airfields and heliports. Certain of the principles used in design are particularly applicable to drainage facilities in arctic and subarctic regions. These and others which are most important for arctic and subarctic drainage are discussed in this chapter. Although this manual is directed primarily to the subject of storm drain design, it is also applicable to design of culverts and open ditches, and the other conventional but important types of drainage structures. The type and capacity of storm drain facilities required to accomplish economically the general objectives outlined in Section 2-2.2 are determined primarily by the promptness with which design storm runoff must be removed to avoid serious interruption of traffic or hazardous conditions on important operational areas, and to prevent serious damage to pavement subgrades. It is presumed that all phases of site reconnaissance have been carefully completed and that information is available that shows topography and natural drainage patterns, groundwater conditions, seasonal frost levels, and permafrost levels, as discussed in TM 5-852-2/AFM 88-19, Chapter 2. Regions not adequately mapped and about which little, if any factual information is available can be evaluated by application of airphoto techniques as described in TM 5-852-9/AFM 88-19, Chapter 8. Even though rainfall is light in arctic and subarctic regions, drainage is an important factor in the selection of an airfield or heliport site and subsequent planning and development. The planner should be cognizant of several features related to drainage to assure a successful design. Some of these are as follows:

8-1.1 Sites should be selected in areas where cuts, or the placement or base course fills, will not intercept or block existing natural drainageways or subsurface drainageways. Adequate provision should be made for the changed drainage conditions.

8-1.2 Areas with fine-grained, frost-susceptible soils should be avoided if possible. In arctic and subarctic regions most soils are of single grain structure with only a very small percentage of clay. Since the cohesive forces between grain particles are very small, the material erodes easily. Fine-grained soil profiles may also contain large amounts of ice lenses and wedges when frozen.

8-1.3 If the upper surface of the permafrost layer is deep, design features of a drainage system can be similar to those used in frost regions of the continental United States if due provisions are made for lower temperatures.

8-1.4 The avoidance, control, and prevention of icing are discussed in Section 2-8.

8-1.5 The flow of water in a drainage channel accelerates the thawing of frozen soil and bedrock. This may cause the surface of the permafrost to dip considerably beneath streams or channels that convey water, and may result in thaw of ice such as that contained in rock fissures and cracks. The latter could develop subsurface drainage channels in bedrock. Bank sloughing and significant changes in channel become prominent. Sloughing is often manifested by wide cracks paralleling the ditches. For this reason, drainage ditches should be located as far as practicable from runway and road shoulders and critical structures.

8-1.6 In many subarctic regions, freezing drainage channels of drifted snow and ice becomes a significant task before breakup each spring. In these areas it is advantageous to have ditch shapes and slopes sufficiently wide and flat to accommodate heavy snow-moving equipment. In other locations where flow continues year-round, narrow deep ditches are preferable to lessen exposed water surface and avoid icing.

8-1.7 Large cut sections should be avoided in planning the drainage layout. Thawed zones or water-bearing strata may be encountered and later cause serious icing. Vegetative cover in permafrost areas should be preserved to the maximum degree practicable; where disturbed, it should be restored as soon as construction permits.

8-1.8 Fine-grained soils immediately above a receding frost zone are very unstable; consequently much sliding and caving is to be expected on unprotected ditch side slopes in such soils.

8-1.9 Locations of ditches over areas where permafrost lies on a steep slope should be avoided if possible. Slides may occur because of thawing and consequent wetting of the soil at the interface between frozen and unfrozen ground.

8-1.10 Provisions should be made for removal and disposal or storage of snow and ice with due consideration to control of snowmelt water. Drainage maintenance facilities should include heavy snow-removal equipment and electric cables with energy sources or a steam boiler with accessories for thawing structures that become clogged with ice. Pipes or cables for this purpose are often fastened inside the upper portions of culverts prior to their placement.

8-1.11 Usually inlets to closed conduits should be sealed before freezeup and opened prior to breakup each spring.

8-2 **GRADING**. Proper grading is a very important factor contributing to the success of any drainage system. The development of grading and drainage plans must be most carefully coordinated. In arctic and subarctic regions, the need for elimination of soft, soggy areas cannot be overemphasized.

8-3 **TEMPORARY STORAGE.** Trunk drains and laterals should have sufficient capacity to accommodate the project design runoff. Supplementary detention ponds upslope from drain inlets should not be considered in drainage designs for airfield or heliports in the Arctic and Subarctic. Plans and schedules should be formulated in sufficient detail to avoid flooding even during the time of actual construction.

8-4 **COMPUTATION OF STORM DRAIN CAPACITIES.** Appendix C includes a design example for drainage facilities to serve a typical portion of an airfield in a *subarctic* region. A separate design example for a typical airfield drainage system in an *arctic* region is not included in this manual as it would follow identical methodology but with two simplifications, as follows: (1) layout would be relatively more austere, usually limited to an aircraft parking apron and a single runway with no parallel taxiway, and (2) as infiltration would be zero, the rate of supply would be the design rainfall rate plus snowmelt. In the subarctic design, the main procedures and steps followed in the determination of storm drain or culvert capacities are given in a step-by-step outline with tables as the design example. It is assumed that the airfield in the Subarctic has a 1-hr rainfall of 0.6 in. plus 0.1 in. runoff from snowmelt, or a total of 0.7 in., a mean annual temperature of about 25 degrees F, the design storm frequency as for most airfields is 2 years, and the infiltration rate for unpaved areas is 0.2 in. per hour. Standard supply curve numbers to be used are therefore 0.7 and 0.5 for paved and turfed areas, respectively. Details are outlined in Appendix C.

8-5 **MATERIALS.** Selection of suitable types of drainage materials for specific projects will be based on design requirements—hydraulic, structural, and durability—and economics for the specific drainage installation. In the Arctic and Subarctic, the flexible thin-walled pipe materials—corrugated metal (galvanized steel or clad aluminum alloy)—have been most widely used for drainage applications because of their availability, weight and transportability considerations, relative ease of installation, and dependability of jointing. Heavier rigid type pipe, reinforced and nonreinforced concrete, particularly with recently developed flexible gasketed joints, and the newer types of plastic pipe are used under certain conditions in the Subarctic.

8-6 **STRUCTURAL DESIGN.** Airfield and heliport culvert and storm drain structural requirements—pipe wall minimum thickness or gages—are usually determined based on minimum amounts of protective earth or pavement cover above the pipe and the maximum aircraft gear loadings to be accommodated. These structural design criteria are given in Chapter 4. Appendix D lists the minimum cover requirements to protect culverts and storm drains in seasonal frost areas from frost heave or from water freezing in the pipe.

8-7 **SERVICE LIFE AND DURABILITY.** These factors will influence drainage material selection. Although the commonly used drainage materials are acceptable in most soil and water environments, there are environmental conditions which limit their service life. Principal among these detrimental factors are corrosion, abrasion, and freezing and thawing action. Protective or periodic maintenance measures to prolong service life where conditions are adverse are difficult, costly, and limited in effectiveness. Often the most practical measure is periodic removal and replacement of damaged or failed drainage components. While this can be readily accomplished under nontraffic shoulders or other less important airfield areas, designs should be based on avoidance of replacement under primary runways, important pavement intersections of high fills. Report "Durability of Drainage Pipe," prepared by the Transportation Research Board, National Research Council, gives guidelines for the selection of durable materials and protective treatments for various adverse environments. The main adverse situations are briefly cited below. This is a complex subject, addressed only in generalities in this manual.

8-7.1 **Corrosion.** Common types of corrugated metal pipe generally corrode when the soil or water is highly acid or alkaline (pH below 5 or above 9) and high electrical conductivity (low soil resistivity) conditions prevail. Mining operations, storage or use of chlorides for snow- and ice-melting, peat or cinder deposits, and salt water in coastal environments are common causes of metal pipe deterioration. Concrete is also vulnerable to acids and certain chemicals (sulfates, chlorides, carbonates) in soils. Plastic, stainless steel or clay pipe or special newly developed protective coatings available for the various pipe materials may be required for use in particularly aggressive environments.

8-7.2 **Abrasion.** This process, more common in culverts than in storm drains, is the wearing down or grinding away of metal, concrete, plastics, clay and other pipe materials and their protective coatings. It occurs when water laden with sand, gravel, stones, ice or other debris flows through, particularly if the flow has a high velocity and if heavy runoff events occur frequently and with long duration. Where severe abrasion is anticipated, extra thickness of pipe materials can be provided, especially along the bottom where wear from bedload movement is concentrated. In some places, abrasive sediment can be removed by providing upstream debris control structures.

8-8 **SHAPE OF DRAINAGE STRUCTURES.** The required hydraulic capacity of a storm drain or culvert can be provided by any of several configurations. While they are usually circular, other factors such as limited headroom, debris accumulation, icing formation, fish passage, fill height, and hydraulic performance may dictate selection of another shape of hydraulically equal capacity—rectangular, oval, arch or multiples. Similarly, options are available in the shape of lined or unlined open drainage channels, ditches or swales with adherence to airfield or heliport lateral safety clearance criteria.

8-9 **MAINTENANCE.** Access for maintenance equipment and personnel is necessary for major drainage channels, debris control barriers and icing control installations. Structures should be periodically inspected, particularly before fall freezeup and after annual spring thaw-breakup periods.

8-10 **JOINTING.** Disjointing, leakage or failure in pipe joints can occur, especially where drainage lines are subject to movement caused by backfill settlement, live loads, or frost action. Flexible watertight joint pipe is available for use in such situations. Most watertight joints rely on use of close tolerance pipe ends connected over a closely fitting gasket.

8-11 **END PROTECTION.** End structures, factory-made or constructed in the field, are attached to the ends of storm drains or culverts to provide structural stability, hold the fill, reduce erosion and improve hydraulic characteristics. A drain projecting beyond the slope of an airfield or roadway embankment is a hazard and subject to damage or failure caused by ice, drift or the current. Drain ends can be mitered to fit embankment slopes or provided with prefabricated flared end sections. Headwalls and wingwalls to contain pipe ends are often constructed, usually of concrete, to meet the several design requirements including provision of weight to offset uplift or buoyancy and to inhibit piping (Section 8-13). Headwalls or wingwalls should be oriented or skewed to fit the drain line for maximum hydraulic efficiency and to lessen icing formation and drift or debris accumulation. The effect of pipeline entrance design on hydraulic efficiency of drainage systems is discussed in Chapter 4. A properly shaped culvert entrance can be an important factor in reducing ponding at an inlet which can wash out an airfield or roadway embankment.

8-12 **ANCHORAGE AND BUOYANCY.** Forces on a drain line inlet during high flows, especially during spring breakup, are variable and unpredictable. Currents and vortexes cause scour which can undermine a drainage structure and erode or fail embankments. These conditions are accentuated in the Arctic and Subarctic by accumulated ice and debris. Corrugated metal pipe sections, being thin-walled and flexible, are particularly vulnerable to entrance distortion or failure. Ends can be protected by providing secure heavy anchorage. This could be a concrete or grouted rock endwall or slope pavement. Rigid type pipe with its shorter sections is subject to disjointing if undermined by scour unless provided with steel tiebars to prevent movement and separation. Buoyant forces must be determined for possible conditions such as blockage of a drainage line end by ice or debris, flow around the outside of a pipe or, in coastal locations, tidal effects. These forces must be counteracted by adequately weighting the line, tying it down, or providing vents. Catastrophic drainage failures have resulted from failure to safeguard against such occurrences, even in temporary situations during construction.

8-13 **PIPING.** Piping is the result of seepage along the exterior of a drain line or culvert which removes backfill material, forming a pipe-like void the full length of the line. Provision of watertight joints (and, if warranted, locked or welded seams in metal pipe) will also reduce exfiltration, a source of seepage flow. The washout of fine-grained soils along the pipeline can ultimately cause its collapse and loss of the overlying embankment. Measures taken to prevent piping include provision of impervious backfill or a large headwall at the upstream end of the line or installation of seepage-preventive metal or concrete bulkheads or collars circling the entire periphery of the drain. The availability of plastic filter cloth which will permit controlled seepage without migration of fine-grained soils provides another useful design expedient to limit piping.

8-14 **DEBRIS AND ICING CONTROL.** It is essential to control debris and icing to achieve desired hydraulic and structural performance and to avoid damages and operational interruption from flooding and uncontrolled icing (see Section 2-8). The debris problem can be solved by providing a structure large enough to pass the material or by retaining it at a convenient adequate storage and removal location upstream from the drainage structure.

8-15 **TIDAL AND FLOOD EFFECTS.** Airfields, with their requirements for large level areas, are often sited on coastal or alluvial floodplains where their drainage systems are subject to tidal and stream flood effects. In arctic and subarctic regions, ice jam and spring break-up dynamic forces and flood heights create major problems, including stream migration, which can adversely affect airfield embankments and protective levees, degrade permafrost, and shift or block drainage outlets. Stream meander control is difficult and costly, especially in the Arctic. Flap gates may be required to prevent backflow into drainage systems, a situation particularly undesirable in tidal or brackish water locations due to corrosive action on drainage pipelines. These gates require a high level of maintenance to assure their operation despite ice, debris, sand or silt accumulation.

8-16 **FISH PASSAGE.** The need to accommodate seasonal fish migration along certain streams should be determined through early coordination with Federal and state fish and wildlife agencies. In some locations fish barriers may be required to prevent migration of undesirable fish species into upstream water bodies. See Section 1-7.11.

8-17 **EROSION CONTROL.** Drainage and erosion control are discussed in Chapter 4. Erosion is important, not just in the design and maintenance of airfields, heliports, and other facilities, but also during construction, when special care must be taken to minimize erosion and siltation from denuded and excavated areas. Temporary siltation basins, check dams, and straw-bale sediment traps should be considered for use in drainage ditches and above drain inlets. Vegetative cover should be reestablished as soon as practicable.

8-18 **INSTALLATION.** Pipe construction in the Arctic and Subarctic, as in other regions, requires shaped bedding and systematic, layer-by-layer backfilling and compaction, and maintaining equal heights of fill along both sides of the pipe. Many culvert and storm drain failures during construction are caused by operating equipment too close to pipe, or failure to remove large projecting stones from backfill near the pipe, or inadequate caution in handling frozen backfill material.

8-19 **SAFETY REQUIREMENTS.** Fuel spillage must not drain into storm sewers or other underground conduits. Safe disposal of spilled fuel can be facilitated by providing ponding areas for drainage so that any spilled fuel can be removed from the surface. Curbs, gutters, and storm drains will not be provided for drainage around tank-car or tank-truck loading or unloading areas, or tanks in bulk fuel storage areas.